Chapter 39. Plant responses to internal and external signals

Figure 39.1. An example of phototropism

Important themes in this chapter:

- Signal transduction pathways
- Plant hormones
  - The discovery of plant hormones
  - Auxin and cell elongation
  - Gibberellin and seed germination
- Plant responses to light
  - Seed germination
  - Photoperiodism and flowering

Light-induced *de-etiolation* (greening) of dark-grown potato

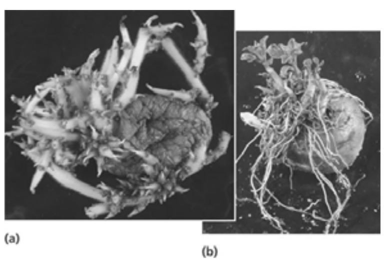
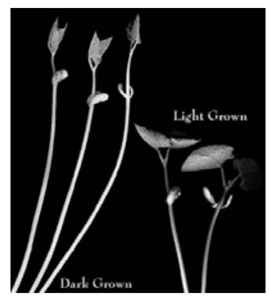


Figure 39.2

Dark-grown plants are *etiolated*

Etiolated plants have
- Small leaves
- Long internodes
- No chlorophyll



Signals: a few examples

- External signals
  - Light (intensity, color, duration)
  - Gravity
- Internal signals
  - Shoot apex to axillary bud (apical dominance)
  - Roots to stomata

Signal transduction pathways link signal reception to response (1)

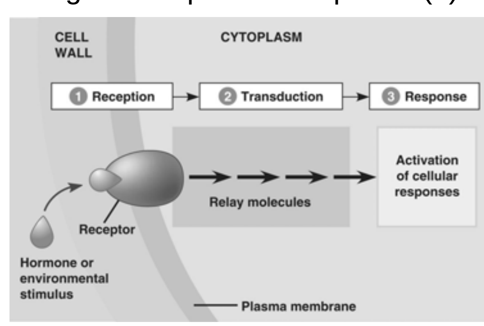


Figure 39.3

Signal transduction pathways link signal reception to response (2)

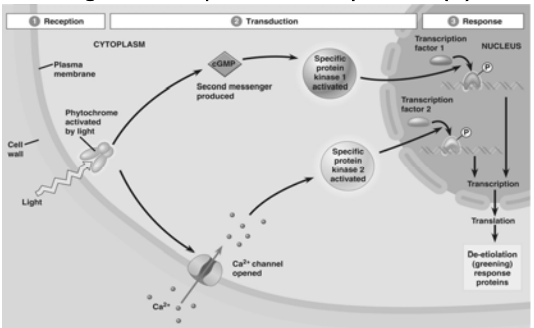


Figure 39.4

Signal transduction pathways link signal reception to response (3)

- Reception of the signal – usually by a protein, often embedded in the plasma membrane.
- Transduction – Relay molecules (second messengers) amplify and transmit signal to nucleus.
- Response – Increased activity of enzymes
  - Making new enzymes ("turning on genes")
  - Activating existing enzymes

Signal transduction pathways link signal reception to response (4)

This model applied to de-etiolation in the potato:

- The signal: light.
- The receptor: a pigment (phytochrome).
- Relay molecules: several are involved.
- Cellular response: new enzymes and newly activated enzymes that participate in chlorophyll synthesis, internode elongation, etc.

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Hormones (this applies to animals as well!)

- Hormones are chemical messengers or signals.
- Hormones are produced in one part of the organism and have an effect in another part of the organism.
- Hormones can have effects at very low concentrations.
- Hormones can interact to control responses.

Phototropism and the discovery of plant hormones (1)

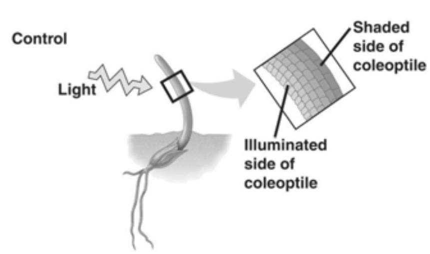


Figure 39.5a. Phototropism of oat coleoptile

Phototropism and the discovery of plant hormones (2)

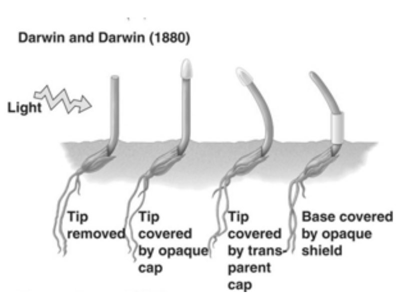


Figure 39.b: The Darwins' experiment

Phototropism and the discovery of plant hormones (3)

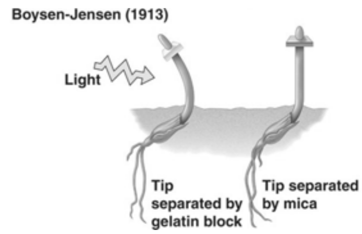
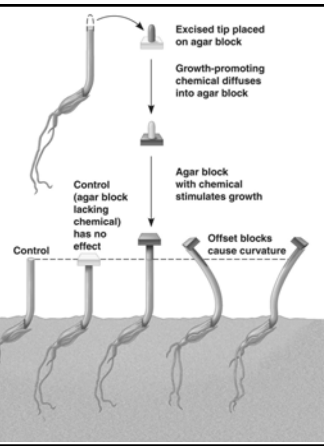


Figure 39.c: Boysen-Jensen's experiment

Phototropism and the discovery of plant hormones (4)

Figure 39.6: Went's experiment



Plant hormones
(Don't memorize this list!)

- Auxin (IAA)
- Cytokinins
- Gibberellins (GA)
- Brassinosteroids
- Abscisic acid
- Ethylene

More details are in Table 39.1

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Auxin and cell elongation (1)

- The most abundant auxin is indoleacetic acid (IAA).
- Auxin is produced in apical meristems (also in seeds, embryo, young leaves).
- Auxin is translocated downward from shoot tip ("polar movement").
- Auxin plays a major role in cell elongation which results in stem elongation.

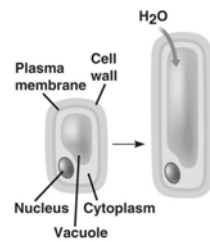
Some other effects of auxin:

- Stimulates root growth.
- Enhances apical dominance.
- Functions in phototropism and gravitropism.
- Promotes xylem differentiation.
- Retards leaf abscission (leaf drop)

How can one hormone have so many effects?
- Effect may depend on concentration.
- Effect may depend on interaction with other hormones.

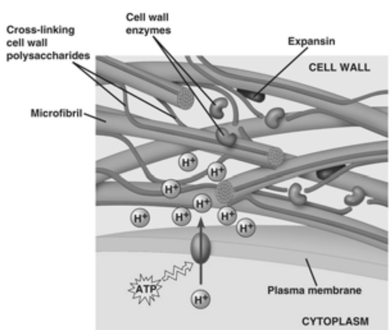
Auxin and cell elongation (2)

Figure 39.8



Auxin and cell elongation (3)

Figure 39.8



Auxin and cell elongation (4)

- In the plasma membrane:
  - Auxin increases the activity of proton pumps
- In the cell wall:
  - Increased proton concentration lowers pH.
  - Expansins activated by lowered pH, expose cellulose microfibrils to cell wall enzymes.
  - Cell wall enzymes digest cross linking polysaccharides.
  - Cellulose microfibrils slide past each other, cell wall becomes more elastic.
- The cell:
  - Takes up water through osmosis, elongates.

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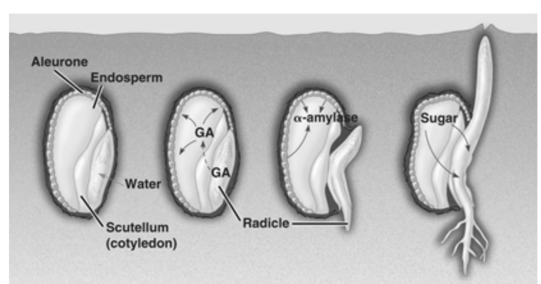
Gibberellins mobilize organic nutrients during grain seed germination (Figure 39.11)



Gibberellins (GA) and seed germination

- An environmental signal results in GA synthesis in embryo.
- GA diffuses to aleurone layer surrounding endosperm.
- In aleurone layer GA “turns on” the gene encoding amylase, a starch digesting enzyme.
- New amylase molecules are synthesized, diffuse to endosperm to digest starch.
- Resulting sugars are absorbed by growing embryo.

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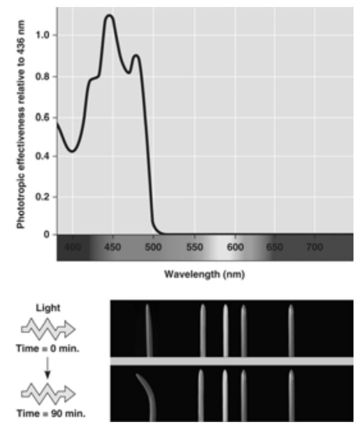
Responses to light are critical for plant success

- De-etiolation
- Seed germination
- Sensing shade
- Sensing the seasons

The action spectrum for phototropism

Figure 39.17



Photoreceptors

- Photoreceptors are pigments that absorb light, initiate cellular response.
- Absorption spectra of photoreceptors match their action spectra.
- Blue light photoreceptors: *cryptochrome*
- Red light photoreceptors: *phytochrome.*

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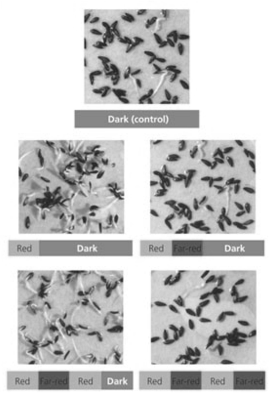
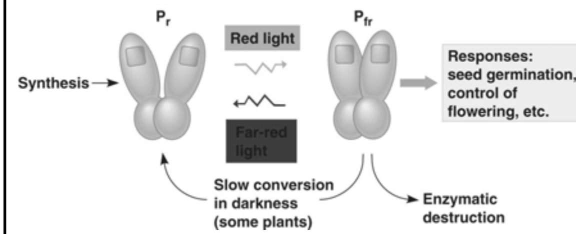
Figure 39.18

The effect of alternating red and Far-red light on lettuce seed germination

Red light = 660 nm
Far-red light = 730 nm



Phytochrome: a molecular switch



P_r absorbs red light, is converted to P_{fr}
P_{fr} absorbs far-red light, is converted to P_r
P_{fr} turns on the plant response to red light

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How do plants detect the passage of seasons?

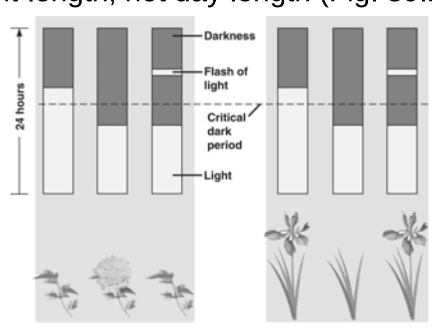
Possible environmental cues:

- Temperature
  - Air
  - Soil
- Photoperiod
  - Day length
  - Night length
- Rainfall
  - Atmospheric humidity
  - Soil moisture

For most non-tropical plants, photoperiod is the best cue

- Short-day plants: flower when days are *shorter* than a critical period.
- Long-day plants: flower when days are *longer* than a critical period.
- Day-neutral plants: flowering is unaffected by photoperiod.

The photoperiodic response depends on *night* length, not day length (Fig. 39.22)



Photoperiodic responses, some details

- The length of the critical day/night length depend on the species and its geographical origin.
- Phytochrome is involved, see Figure 39.23
- The critical photoperiod is sensed by leaves, the flowering response occurs in buds, suggesting that there is a flowering hormone.

Is there a flowering hormone? (The *florigen* mystery)

In this figure (39.24), the left-hand plant received the critical photoperiod, but not the right-hand one